Enaction and Visual Arts : Towards Dynamic Instrumental Visual Arts

Annie Luciani

Enaction and Visual Arts: Toward Dynamic Instrumental Visual Arts

A. Luciani
ACROE-ICA, INPG, Grenoble, France
E-mail: Annie.Luciani@imag.fr

Abstract

This paper is a theoretical paper that presents how the concept of Enaction, centerd on action and interaction paradigm, coupled with the new properties of the contemporary computer tools is able to provoke deep changes in arts. It examines how this concept accompanies the historical trends in Musical, Visual and Choreographic Arts. It enumerates the new correlated fundamental questions, scientific as well as artistic, the author identifies. After that, it focuses on Dynamic Visual Arts, trying to elicit the revolution brought by these deep conceptual and technological changes. It assumes that the contemporary conditions shift the art of visual motion from a "Kinema" to a "Dyname", allowing artists "to play images" as "to play violin", and that this shift could not appear before our era. It illustrates these new historical possibilities by some examples developed by the scientific and artistic works of the author and her co-workers. In conclusion, it assumes that this shift could open the door to a new genuine connection between arts that believed to cooperate but that remained separated during ages: music, dance and animation. This possible new ALLIANCE could lead the society to consider a new type of arts, we want to call "Dynamic Instrumental Arts", which will be really multisensorial: simultaneously Musical, Gestural and Visual.

1. Enaction and Arts

As focused in the Enactive project [Enactive 2002], "Enaction" is understood in a large sense of considering the role of action (and further of interaction, action could not exist without interaction) at the center of the human activities whatever they are, for human biological survival as well for human cultural creation of new objects or symbols.
Arts could be considered by focusing whether on the formal design of artworks (composition, scenarios), whether on the performance activity (musical performance, interactivity, open artworks).

In both domains, some years ago, such association, "Enaction" and "Artistic creation", should be either provocative or of a few interest. What could be, nowadays, the link between Enaction and Arts? And, does this link support a new general paradigm in Artistic creation process?

Since the XIX century industrial revolution, creation activity in arts was mainly considered as an abstract activity starting the clearly cut separation between composer and instrumentalists in Music, designers and producers in fine arts, or choreographers and dancers in choreographic arts. The apogee of such period was at the middle of the XX century with the primacy of formal approaches in arts, as the serialism in music or the conceptualism in visual arts". The ultimate point was in Music the Darmstadt school "Domaine Musical" (1955-67) founded by P. Boulez, the leader of the European avant garde and his book entitled "Penser la Musique aujourd'hui" [Boulez 1987].

At the beginning of the use of the computer in arts (at the middle of sixties), the main stream of theories and uses focuses on the conquest of "immateriality" allowed by computer. Keywords were: "to overcome the limit of the matter", "to reach a pure thinking of musical cues", "Music for mind", "Abstraction for visual cues", "breaking the real", etc.

Recently, about ten of twenty years ago, after the relative failure of so radical theories, and under the recent technological propositions of interactivity allowing the computers to be more and more adapted to the human senses and action, arts became more and more interactive. The "instrumentality" is progressively re-introduced as a way of design through its sub-instance of interactivity. The role of "gestures" has been rehabilitated, not only to produce sensorial predefined events but to properly create artistic qualities. In music, performance, previously considered as the end of the musical production process, as a kind of "sonification" of the musical pre-written score, was rehabilitated as a creative process in itself, not only in musical improvisations as in specific musical styles (jazz, free music, etc.) but as a creative process in itself, as in open or interactive composition. Such approaches shift the creation process from the formal organization of musical of visual events to the production process itself. Simultaneously, the role of the "instrument" as a tangible object able to feed and steer the creative process by imposing constraints and of the "instrument trade" was rehabilitated against the "free constraint approaches".

Such theoretical shift is totally in adequacy with the concept of enaction. More, Arts is probably the realm (beside biology), in which high level media of communication and of cultural data are produced by means of closed-loop sensori-motor interaction.

This historical movement is particularly clear in Music, which needs, as an "allographic art", another way of representation and of design, different than itself: the musical graphical notation. It is less evident in visual arts or choreographic arts, that are "autographic arts" being in themselves their own tools of representation and design. However, it traverses all the Arts that we called "Dynamic Instrumental Arts". "Instrumental arts" refer to arts that need a physical medium (object, body) to exist. Dynamic refer to the fact that at any stage of its production process, sensorial artistic events are evolving events. Basic Dynamic Instrumental Arts are Music, Visual Arts and Choreographic arts. Each of them addresses the question of the role of the instrument and of the interaction between artists and their instruments in specific ways according to their own historical positioning and their own particularities.

Indeed, the word "instrument" is usually reserved to the musical realm. However, if we dare to use it in a more general meaning, as a physical mediator able to produce exteroceptive stimuli, visual and auditory, by an action of human body on it, we understand immediately that all the arts that need such mediator are necessarily temporally-based and interaction-based. Physical interaction, sensory-motor coupling, gesture, instrument, movement, etc. are complementary components that are always present and that are always cooperating in all sensory-based (conversely than language based) arts. Conversely, the question of the link with the interactionnal performance activity and the conceptual processes is raise as one of their core question. One main property of such "instrumental concept" is to reveal the implicit familiarity of artistic creation process with the "enaction concept".

In Musical arts, the concept of instrumentality is an ancestral concept that exists from the origin of the music and of the sound production. The pair instrument - instrumentalist is always present in music, even so in computer music with the field of "Digital Musical Instruments". The main fundamental question in music is the link between the inevitable instrumental process and the musical notation and composition, and the link of the musical composition with musical perception and cognition.

In Visual Arts, two sub-domains have to be distinguished: arts that produce "static objects and events" (sculpture, paintings, etc.) and arts that produce "movements" or "moving objects and visual events" (movies, automata, animation).

In the first sub-domain, instrumentality is a native and ancient practice. The role of the physical matter and of the interaction with it is widely recognized and respected. Differently than Music, such autographic arts don't need external and foreign way of notation for their design and their composition. There is no problems of notation as it exists in Music and no failure between compositional activity and other musical activities such as musical performance .

In the second sub-domain, except in some minor cases like shadows' theater or puppet theater, instrumentality is difficult to define before the arrival of the computer. We cannot play with objects producing pure visual events as we are able to play with a violin. Movies and animation with conventional media (cinema or video) do not implement <u>explicitly</u> the instrumental concept.

From the point of view of the novelty brought by computers, in both cases, computers triggered really a revolution in the visual art of motion by allowing the designing of "objects" that can be manipulated as " violin" to produce visual evolving events.

And in both cases, Enactive Interfaces and Enactive Knowledge, as envisioned in the Enactive project [Enactive 2002] are means to experiment and to rehabilitate the preeminent role of the interaction and of the matter in the visual artistic process.

In Choreographic arts, as in theater's arts, "instrumentality" is not an explicit usual concept, the human body being its own instrument. The concept of instrument has been introduced recently with the notion of "augmented body" by external devices and equipments able to capture the motion of the body. Such motion, transformed in a signal, becomes an "object" that can be processed and applied to control other objects and others instruments. Computers lead to bring together musical arts, visual dynamic arts and choreographic arts, around a common "instrumental" concept of instrumental interaction and design. Correlatively, As in music and in visual motion, the core difficult non-solved question remains that of the notation and of the composition of such evolving events.

Summarizing in a differentiate way the major questions risen by each of the main Dynamic Instrumental Arts, we could say:

• In Music, the haunting question that traverse the contemporary schools being the relation between "instrumentality and composition, are new computers tools and new ways of interaction with computerized instruments, able to overcome this frontier or not? Are the concept of Enaction and, its technological instance able to reconcile the opposites, the enemy brothers "the mind" and "the body"?

• In Visual static arts, is the generalization of interactivity concept able to instill in the production process, as in craft process, the minimum of instrumentality required to support craft know-how?

• In Visual Dynamic Arts, is the notion of virtual manipulable objects able to produce visual dynamic arts with the same level of quality for the visual shapes and for the expressivity of the motion? and is the motion processing able to overcome the duality between space (autographic representations) and time (allographic representations)?

• In choreographic arts, is computers a step in the motion representation without the creation of a break between choreographic performance and choreographic design, that is nowadays a core and passionate question?

From such contemporary questions asked by such arts, some relevant – but non-exhaustive - issues can be listed:

1. What common issue? Is the motion and the gesture, (with its processing, its rendering, its production, its notation) a common feature shared by all such instrumental dynamic arts? Could motion and sgesture be common means to bring them near or to merge them in a very novel and genuine way?
2. What types of computer models and computer representations and interfaces should be the best candidates to receive gestures and to produce genuine movements?
3. What type of links between the primary evolving event (gesture, movement, action) and the sensory outputs visual and auditory: Trivial links only as those proposed now in computer graphics and animation? Arbitrary links as those proposed in the mapping process in computer music? Others links?
4. Can we speak about gesture 's composition independently of the 3D object that is receiving or producing such motions? Can we apply every kind of gestures and action on every type of production process?
5. What types of link between the design process and the performance processes
6. What should be the relation between the enactive concept, well revealed by the necessity of the gestural interaction, and the artistic emotion? What is the role of the instrument and of the interaction in the shift from the production process to the esthetic process?

2. Theoretical considerations: "Thinking the image as emerging from the motion"

The introduction of the computers in visual arts started from the available software produced either for the media industry (photograph, printing, in image processing, or for 2D or 3D CAD tools. (see following table).

	Static images	Animated images
Image processing	Image processing software (Photoshop, etc.)	Video Processing (Final cut, Premiere, video compositing techniques, etc.)
Image synthesis	2D synthetic images (line-based, pixel-based) 3D synthetic objects (3D software)	2D Computer animation-(FlashMX) 3D Computer animation (Softimage, Maya, Blender, 3D studiomax, Director)

They are mainly based whether on "images" or on geometrical shapes. Since recently, in the computer animation available software, motions are mainly represented as explicit temporal evolutions of shapes, whether by the frame-by-frame techniques or by the evolution (or kinematic) functions techniques.

Movies technology is defined by the fact that the time is explicitly represented. We can say that they run at the phenomenological level, i.e. they aim to reproduce what there is directly observable. In other disciplines (as in maintaining of complex systems), such level is sometimes called "symptom level" or "surface level". Such techniques are based on an analysis-synthesis paradigm, saying that what it is observable and objectively analyzable should be reproduced by the inverse process used for the analysis. The best example is the analysis and synthesis of signals by Fourier transform functions. Conventional cinema belongs to such vision of motion: cinema performs a sampling of observed motion and conventional animation synthesizes motions in a same way. Similarly, computer kinematic-based animation (including key-frames, frame-by-frame, evolution functions, explicit morphing techniques) refers to signal-based synthesis process. Thus the main stream in computer visual arts consists in the use of "signal-based paradigm": Multimedia techniques on signal processing or synthetic motion in signal synthesis.

Motion capture as well belongs to signal processing techniques. When the motion is acquired by means of adequate sensors, motion signals can be processed: noise reduction, features extraction, signal re-targeting. Such signals can be exploited as input of systems, for example by controlling, in a time-explicit way, the evolution of another feature.

Despite the widening such techniques brought in the production of new motions and despite the simplification of the production process they allow with re-using processes, basic properties of motions cannot not reached in an elegant and efficient way and the motion produced are limited in complexity and in expressivity.

The main reason is that signal-based methods are not by principle the substratum of interaction paradigm. Signals are results of the physical interaction (for example, the motion of the body is produced by a body in interaction with its physical environment). The nature of the provided motions is in the bodies and in their interaction. Signals represent the motion and not the cause of the motion. Thus even if the original acquired motion signals encode the properties of the bodies and of their interaction, motion signal is a downstream representation of the cause of the motion and motion signal post-processing is by principle unable to maintain such properties in the consistent way of their production conditions. In other - more scientific – words, the signal processing tools are not usable to process the properties of the bodies and their interaction that produce the signals.

The strength of phenomenological (signal-based) models consists in the fact that they correspond to an explicit description of possible observed motions and performances. Theoretically, any motion can be represented by such methods. Nevertheless, their complexity increases dramatically when we want to represent high level qualities as "softness", "hardness", "rhythm changes", "dynamic complex correlations of complex shapes motions", "emergent non predictable evolutions. Exemplary cases are when several evolutions are correlated in time, as the usual correlations between displacements and correlations (during the falling of a leaf, during the evolution of air bubbles in an aquarium, etc…), or when we are faced in a complex motion in which dynamic variations occur during motions: slowing-down/acceleration, transients, or state changing, etc. More complex these changes and correlations are, more inefficient signal-based representations of motion will be.

This led to the development of generative models of motion. Here "generative" means processes in which the time is implicit and in which the computation process produces families of evolution functions according to the parameters of the generative processes. The capabilities of simulation of computers, that are really new comparatively to our previous creation tools, allow to overcome such limitations. But the important fact is that then, it proposes a radical paradigm shift:

- ➔ from phenomenological (signal based, surface based, symptom based) direct representations (models) to generative representations (generative plausible cause modeling, genetic plausible rules definition) able the generate the expected phenomena.
- ➔ in other words, from the description of the observed motion to its generation by means of the simulation of a generative process.

Such generative representations shift the artistic process, from the activity on the perceptive items themselves to the activity to define the conditions of their production. This simple fact is on adequacy with the historical evolution of the center of interest of Arts. Contemporary interactive or open artworks operate similar shifts, implementing really an enactive situation in the creative process.

Thus, contemporary artistic theories or artistic models are stressed between two complementary and not always convergent needs, sounding as a major contemporary dilemma:

• the freedom in the design which characterizes the phenomenological approaches,

• the conceptual and practical powerful for complexity and representation of motion relevant features brought by the generative approaches.

The following questions are now opened:

• What kind of generative models of motion?

• How can we solve the artistic dilemma between free design underlain by motion analysis-synthesis methods and complexity and relevance of produced motion underlain by generative approaches ?

3. "Kinema" vs "Dyname"

Three fundamental basic ideas, that are in our opinion totally relevant with an enactive approach, can enlighten the previous theoretical questions :

• Even if the phenomenological (signal-based) representations (modeling) of the motions is attractive for its completeness, we affirm that to be phenomenologically relevant – i.e. to reach a significant representations of the relevant phenomenological features – motion synthesis processes have to be based on generative models.

• The facility to design such models and, in case of failure, the come-back to a pure direct phenomenological description and its links with generated motions have been asked as a secondary stage of modeling.

• The relation between such produced evolving visual events and the mechanisms able to trigger sensible relevant qualitative gestalts (expressiveness, emotions, aesthetic features, etc.) will be asked in parallel as a property of the modeling process itself.

Generative approaches

All generative approaches assume more or less this philosophical point of view. Nevertheless, there are several types of generative approaches. Following the fruitful typology defined by Newman and Comper [Newman 1990] in biological morphogenesis processes, we consider that there are two types of complementary generative models of motion:

- Generic models (or processes, or systems)
- Genetic models (or processes, or systems).

Generic mechanisms are defined as those physical processes that are broadly applicable to living and non-living systems, such as adhesion, surface tension and gravitational effects, viscosity, phase separation, convection and reaction-diffusion coupling. They are contrasted with 'genetic' mechanisms, a term reserved for highly evolved, machine-like, bio-molecular processes. As Newman and Comper said: "Generic mechanisms acting upon living tissues are capable of giving rise to morphogenetic rearrangements. Many morphogenetic and patterning effects are the inevitable outcome of recognized physical properties of tissues, and generic physical mechanisms that act on these properties are complementary to, and interdependent with genetic mechanisms. Major morphological reorganizations may arise by the action of generic physical mechanisms, that could be stabilized and refined by subsequent evolution of genetic mechanisms."
In computer graphics, these two categories correspond basically to:

- Physically-based models, (or physic-chemical models) modeling the dynamics.
- Behavioral models". Agent-based models, developed in artificial intelligence and artificial life, and sometimes called

There are two major types of behavioral models: Genetic algorithms and Agent-based models.
• Genetic algorithms, as L-systems or cellular automata, aim to model developmental processes based on genetic evolutions.
• Agent –based models are mainly based on implementation of perception-decision-action processes, to model autonomous behaviors. In computer graphics they are widely used in modeling of living growing [Prusinkiewicz 1993, 1999, 2002] [Lindenmayer 1992], living behaviors, evolutionary processes, morphogenesis processes, autonomous behaviors [Sims 1991, 1992, 1994] [Musse 1999], and emergent cooperation between actors [Panatier 1998] [Heguy 2001] [Sanza 2000].

There are three types of physically-based models:

- Continuous models

The phenomenon (for example, deformation of an object) is represented in a continuous formulation. Each model corresponds to a specific phenomenon: rigid and flexible objects [Terzopoulos 1988a] [Terzopoulos 1988b] [Baraf 1992] [Terzopoulos 1993], Metaxas 1996], tridimensionnal elasticity, Navier-Stokes equation for turbulent fluids, matter transport for granular material, friction models [Baraf 1991] etc. Thus, such differential partial equations are solved according to various methods: finite difference method, implicit and explicit resolution etc.

- Mesh-based discrete models

The most known method is basically the finite elements method (FEM), used to calculate the dynamic behaviors of objects. FEM was widely used in mechanics to compute deformations of compact mechanical bodies. It is also widely used to solve problems as variational problems in physics. This method is a geometrically-based physical one in the sense that the geometrical features (shape, volume) of the body are given and discretised in space by geometrical basic elements, constituting a mesh. Another mesh-based methods are those used to simulate behaviors of continuous medium (fluids, gas, etc.), called lattice methods (Lattice Gas Method, etc.). They were rarely used in Computer Graphics.

- Particle-based discrete models

Particle-based models appear more recently in Computer Graphics. They were used since the beginning of computer calculations in physics, as in the Los Alamos laboratory to compute complex behaviors of turbulent fluids. There were stopped due to the low computation power of computers at that time. The exponential increasing of the computational power of computers renders newly attractive this approach

From an enactive creation process point of view

Continuous models are mainly "one-shot" models, able to produce highly realistic motion, but less reusable, and less easy to design and to manipulate. They do not offer sufficient versatility for a motion creation process. They are restricted in a specific use in physical modeling to knowing and experiment a specific physical phenomenon or in media industry to produce special specific effects.

Mesh-based models offer the possibility to design a wide variety of phenomena. They are attractive because of the direct link with the definition of the shapes of the objects they offer. Nevertheless, they are restricted by their basic assumption on the contiguity of the

modeled matter: The forces applied within the elements are contact and cohesive local forces representing the contiguity of the matter. Thus, several complex phenomena that are of a great interest to day (chaotic phenomena, transients, non-linearities, complex dynamics, etc…) are not able to obtain. That limits their domain of applicability in arts.
In addition, these two types of models are quite complex to use in an artistic creative process. They require long time for their designing and implementation, slowing down the process of trial and discovery inherent of artistic creation activity.

The usual understanding of Particle-based discrete models, improperly often named mass-spring models, (physical objects being modeled by a set of punctual masses linked by basic potential or dissipative interaction) reveals that, in computer graphics, physical modeling is understood only as an implementation of the rules of physics, rather than as a generic method of modeling, at the same level of abstraction that neural or cellular automata networks. Used in such way, its modeling power as well as its computational efficiency is obviously limited. As described by their founders [Greenspan 1973, 1997][Cadoz 89][Luciani 1991], physically-based particle modeling is a generic modeling concept, minimally based on the explicit duality of variables, extensive variables (EV) and intensive variables (IV), and the basic action-reaction principle and able to model all the dynamic features of evolving phenomena we can act on and we can perceive, more generally we can observe and control.

4. Philosophy of physically-based particle models

From this abstract point of view, a physically-based particles model is a network of dynamic automata, similar to the well-known Kirchhoff's network in Electricity, in which behavioral differential components producing extensive variables are linked by differential interaction components producing intensive variables. This type of network can be seen as a type of cellular automata calculating real states from elementary differential equations, instead of logic states.

Such approaches belong to a wide stream of theories showing that complex phenomena (as auto-organization, complex stable shapes, stable state changes, etc…) can be produced by physical elementary interactions.

Conversely than mesh-based approaches or continuous physical models approaches, such models are topologico-dynamically oriented. They are astonishingly similar than those developed in the past by the gestalt theory and rediscovered on studies in cognitive grammars [Petitot, 1994]. They belong to the same way of thinking that the concepts of "semiophysics" by R. Thom [Thom 1988], "phenophysics" by J. Petitot [Petitot, 1989] as "Physics of meanings", or those of qualitative of naïve physics of [Smith 1993] and [Hayes 1985].

5. Shape vs. Motion

Putting the emphasis on generative models of the motion has significant consequences on the representation of the shapes of the objects and more generally on the morphological and visual features of the spatio-temporal visual phenomena:

• using a kinematic description of the motion leads to map this motion on a pre-determined shape. In the case of this shape is deformable, it leads to define shape parameters that can be modify by the temporal evolution function, or to produce directly the set of deformed shapes (as in the morphing process). As already said, qualitative relevant behaviors, as thresholds passing, critical points, bifurcations, states changing, emergent behaviors, cannot be reached by such approach.

• Using physical models based on geometrical descriptions (as FEM methods, variation methods) limits also the dynamic phenomena to those that can be described under the basic assumption of such method, i.e. the contiguity of the matter. It is not possible to introduce easily distant dynamic correlations as those provided by distant interactions (with no contact).

• using physically-based particle models, the possible motions than can be described blew up, from conventional motions (displacement of more or less rigid bodies, deformable objects) to complex behaviors exhibiting emergent non-linear features. Conversely, the shape and more generally the morphological and topological organization of the space is lost and has to be reconstructed.

Thus a duality appears between the shapes and the motions: more is the focus on shapes, less is the reachable richness of the motion, and vice-versa. It is what we call the "duality motion/shape", that neither Computer 3D graphics nor Computer animation are able to overcome for the moment.

This duality is due to a fundamental discrepancy between mechanical phenomena and optical phenomena, between what we call "The graviton effect", (i.e. the mechanical matter that produce the motion and the mechanical shape that can be touched and felt with the body) and "the photon effect", (i.e. the electromagnetic matter that produce the visual shapes and visual effects). This leads to point the fact that the notion of shape is "an ambiguous notion. As Janus figure, shape has two faces, one looking to the physical materiality of the object, one looking to optical property (Figure 1).

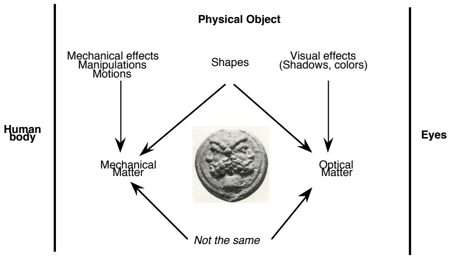

Figure 1. Mechanics vs. Optics: the ambivalence of the shape.

Except in images produced exclusively by geometrical processes (geometrical drawings or synthetic 3D images), in all other cases, images engrave motions. Even if objects are at a greater scale of time than usual evolving phenomena such as mountains, trees, etc., expressing the immobility, we can remark that the morphological features (the shape, the texture, etc…) contain more or less explicitly the trace of the evolution. From this observation, it appears that the critical frontier in visual representation is not the distinction between morphology (shapes) and rendering (light) as usually considered in Computer Graphics, but between optical matter, represented by electromagnetic field, and mechanical matter represented through forces, in which the first produces pure visual features (color, shadows, etc.) and visual shape and the second produces mechanical shapes and motions. Visual features are then related more to the geometry of the space, since mechanical shapes and motion are related more to mechanical dynamics.

It means that there are two notions of shapes, one purely geometric, more related to vision, and another "physical", more related to resistant matter, the texture being the frontier between the two spaces? Indeed, shapes have, as the Janus figure, two faces or two determinants. They emerge from two completely different processes, optical and mechanical, and thus, a single object can paradoxically exhibits several shapes, or several "contours": the visual shape and the mechanical shapes.

More, the visual shape and the mechanical shapes of a single object have no reason to be always identical. Several situations illustrate this paradox. A rainbow or the mirage of an oasis in the hot desert has a visual shape but doesn't have mechanical contour. We can traverse them or walk through them. Conversely, a perfectly transparent door has not a visual contour but has a hard mechanical shape. The visual shape is sensed by eyes whereas the mechanical shape is sensed by the body.

Basically, the visual features are nothing else but the singularities of the interaction between photons and electromagnetic matter. The visual shape (the visually detected flatness, the visually spherical shape etc…) is the geometrical locus of the spatial singularities of the interaction light – optical matter. Thus, visual events are intangible. Other classical examples could be geometrical drawing and synthetic 3D images produced by pure geometrical representations.

In usual rigid objects, the visual shape seen by the eyes is at the same spatial location as the mechanical shape "seen" by the body. Although these objects are usual, nevertheless, they represent specific cases where the matter is 100% (99,99%) mechanically rigid and simultaneously 100% (99,99%) electromagnetically rigid (opaque). But what about flames, rainbow, water, fluids, translucent pastes, glasses etc?

Furthermore, what about objects like cat fur or hair, that are not 100% (99,99%) mechanically rigid, and thus exhibit several mechanical contours. In other words, and in a funny way, all what it is happening in terms of "contour" as a primary cue of space organization, depends on the percentage of the optical and of the mechanical rigidity.

More, a thing that could be considered as a single object can exhibit several mechanical contours. If you put a force sensor on the palm of the hand when stroking your cat, the force detected will be very low when the hand is in the fur, higher when it is on the deformable skin and higher when it is touching the skeleton. This means that a single entity - our preferred pet - may exhibit several mechanical contours, described by several thresholds in the singularities of the physical interaction.

In conclusion, the features drawn by mechanics (mechanical shapes and motions) and those drawn by optics (optical shapes and visual patterns as colors and shadows), *without no resort to explicit geometrical 3D modeling*, are the two basic arches of Dynamic Visual Arts, founding the an instrumental paradigm in Visual Arts as:

"Puppet and Shadows theater paradigm"

6. Examples

To illustrate this paradigm, we develop several models of motions and correlated shapes, <u>only</u> based on physically-based particle formalism, <u>without NO</u>

explicit geometrical shape description and modeling: from displacements of rigid or articulated bodies [Nouiri 1994] [Chanclou 1995] [Chanclou 1996] [Jimenez 1993] to complex emergent dynamic phenomena (as crowd behaviors [Luciani 2003]), including all types of deformations, complex motions as chaotic or non-linear evolutions (avalanches, collapses, fractures, etc.) [Luciani 2000] and all the various states of the matter (fluids, gas, solid, pastes, etc.) [Luciani 1995b] [Luciani 1995a].

Following, we illustrate some models and visual results. All of them are able to be manipulated by means of gestural inputs and force feedback devices, as expected in the instrumental "Enactive" paradigm.

Puppet animation with physically-based simulation and force feedback manipulation

Figure 2. Real time Physically-based puppet manipulated by feet by means of 2*2D force feedback sticks

Real time molding of a simulated plastic paste with gestural feeling [Luciani & al., 1991]

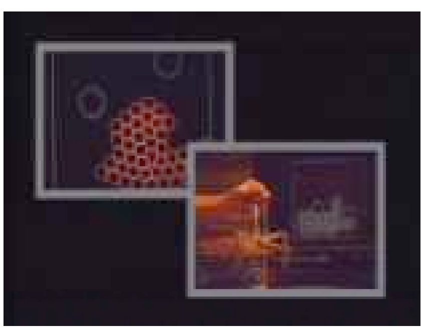

Figure 3. Feeling the matter: real time molding of plastic material by means of force feedback pliers.

Modeling the engraving process

We develop a physically-based visualization process, that allows to expand the motion in space, by a dynamic process based on the "engraving metaphor". [Habibi 2002].

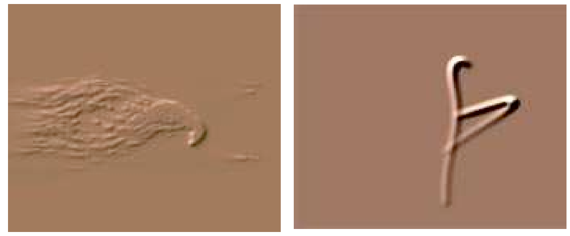

Figure 4. Physically-based particle model of engraving process

Modeling large scale dynamic phenomena: water-like and atmospheric-like propagation

The following images illustrates the use of the CORDIS-ANIMA physically-based formalism to model a non-linear large scale propagation effect, as in "aurora borealis".
The first row shows the basic model of the propagation effect: a spatial string excited by a non-linear relaxation input.
The second row shows the spatial propagation of the underlying non-linear motion in space, by means of the Engraved Screen Software based [Habibi 2002]

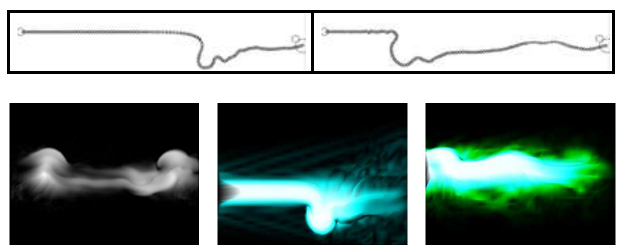

Figure 5. Physically-based model and simulation of large scale phenomena: "Aurora Borealis"

The following images illustrate a second large scale dynamic phenomena effects as smoke propagation and turbulences, rendered with the Physically-based visualization tool "The Engraved Screen".

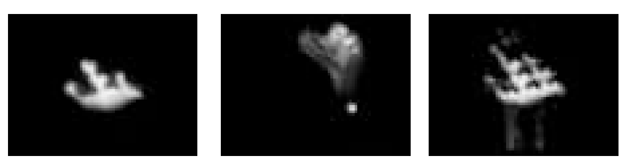

Figure 6. Physically-based model and simulation of large scale phenomena: "smoke flowing and dissipation"

The following images illustrate a third large scale dynamic phenomena effects as water propagation effects rendered with the physically-based visualization tool “The Engraved Screen”.

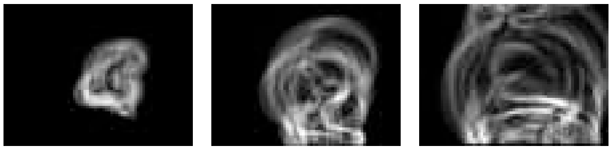

Figure 7. Physically-based model and simulation of large scale phenomena: “water propagation”

All the results presented here have been used in artistic works [Cadoz et al. 1996], [Luciani 2000b].

7. Conclusion: Towards a new alliance between Dynamic Instrumental Arts

In this paper, we defended the idea that an historical revolution is happening in visual arts that is more than the usual interactivity and than the enlarging of visual effects. We stated that if in Music, computers will probably open the door to a reconciliation between the sound level and the composition level, if in Choreography, computers will probably open the door to a possible generic notation of human motions, in visual arts, computers open the door to consider visual arts of movement as an instrumental arts: “playing visual objects sources as playing violin”. Not only as implemented in interactive artistic installations, but more, as in a strong physic-to-physic closed dynamic interaction.

Thus, (1) after the revolution of mechanical automata, as initiated by Jacques de Vaucanson [Vaucanson], (2) after the revolution of “capturing the photon” as initiated by Nicéphore Niepce [Niepce], both revolutions opening the era of cinema as the art of motion, computers with algorithmic representations of physical world and interfaces to physically act of these representations, shift the art of “Kinema” to an art of “Dyname” (as an art of the visual manipulable causes) offering the most generic way to combine the two main artistic quality of the visual: the immateriality of the images to the materiality of the motion.

Thus, the age of a genuine connection between dynamic arts is starting: musical arts, choreographic arts and visual arts having all the panoply of the tools arts need: designing by mains of notations, playing to create impossible writable phenomena, formal and playable processing of such complex sensible data.

This possible new *Alliance* between arts that from ages believed to cooperate but remained separated, could lead the society to consider a new type of arts, we want to call “Dynamic Instrumental Arts”, simultaneously Musical, Gestural and Visual.

8. References

[Enactive 2002] FP6 project « Enactive Interface » IST 2002 – 0002114. www.enactivenetwork.org

[Boulez 1987] Pierre Boulez. Penser la musique aujourd’hui. Ed. Gallimard, France. 30/11/1987

[Newman 1990] S.A. NEWMAN, W.D. COMPER - "'Generic' Physical Mechanisms of Morphogenesis and Pattern Formation." p1-17. Development, Vol 110, Issue 1 1-18, Copyright © 1990 by Company of Biologists

[Prusinkiewicz 1993] P.Prusinkiewicz, M.S. Hammel, E. Mjolsness - "Animation of Plant Development." p351-360, Computer Graphics Proceedings, annual Conference Series1993 (SIGGRAPH’93 Conference Proceedings).

[Prusinkiewicz 1999] P. Prusinkiewicz: Modeling Plants and Plant Ecosystems: Recent Results and Current Open Problems. Computer Graphics International 1999: 110-

[Prusinkiewicz 2002] P. Prusinkiewicz: Geometric Modeling without Coordinates and Indices. Shape Modeling International 2002: 3-6

[Lindenmayer 1992] Lindenmayer A, Jürgensen H. 1992. Grammars of development : discrete-state models for growth, differenciation, and gene expression in modular organisms. In: Rozenberg G, Saloma A, eds. Lindenmayer systems. Berlin: Springer-Verlag, 4-21.

[Sims 1991] K.Sims. "Artificial Evolution for Computer Graphics" Computer Graphics (Siggraph '91 proceedings), July 1991, pp.319-328.

[Sims 1992] K.Sims, Towards a Practice of Autonomous Systems: Proceedings of the First European Conference on Artificial Life , MIT Press, 1992, pp.171-17

[Sims 1994] K.Sims, "Evolving Virtual Creatures" Computer Graphics (Siggraph '94 Proceedings), July 1994, pp.15-22.

[Musse 1999] Soraia Raupp Musse , Marcelo Kallmann , Daniel Thalmann, Level of Autonomy for Virtual Human Agents, Proceedings of the 5th European Conference on Advances in Artificial Life, p.345-349, September 13-17, 1999

[Panatier 1998] Cyril Panatier , Hervé Luga , Yves Duthen, Collective learning for spatial collaboration, Proceedings of the fifth international conference on simulation of adaptive behavior on From animals to animats 5, p.477-482, September 1998, Univ. of Zurich, Zurich, Switzerland

[Heguy 2001] Olivier Heguy, Yves Duthen, Alain Berro . Learning System for Cooperation in a Virtual Environment . Dans: SCI?2001 The 5th World Multi-Conference on Systemic, Cybernetics and Informatics , Orlando, Florida USA. 22 juillet 25 juillet 2001.

[Sanza 2000] Cédric Sanza , Cyril Panatier , Yves Duthen, Communication and Interaction with Learning Agents in Virtual Soccer, Proceedings of the Second International Conference on Virtual Worlds, p.147-158, July 05-07, 2000

[Terzopoulos 1988a] D. Terzopoulos, K. Fleischer. "Modeling inelastic deformation: Viscoelasticity, plasticity, fracture,", Computer Graphics, 22(4), Proc. ACM SIGGRAPH'88 Conference, Atlanta, GA, August, 1988, 269-278.

[Terzopoulos 1988b] D. Terzopoulos, J. Platt, A. Barr, K. Fleischer, "Elastically deformable models," Computer Graphics, 21(4), 1987, 205-214, Proc. ACM SIGGRAPH'87 Conference, Anaheim, CA, July, 1987. Translated to Japanese by Nikkei-McGraw-Hill and published in Nikkei Computer Graphics, 3(18), 1988, 118-128.

[Baraf 1992] D. Baraff and A. Witkin. Dynamic simulation of non-penetrating flexible bodies. Computer Graphics 26(2): 303-308, 1992

[Terzopoulos 1993] D. Terzopoulos, D. Metaxas, "Dynamic 3D models with local and global deformations: Deformable superquadrics," IEEE Transactions on Pattern Analysis and Machine Intelligence, 13(7), 1991, 703-714. Special Issue on Physical Modeling in Computer Vision. Reprinted in Model-Based Vision, H. Nasr (ed.), SPIE, 1993.

[Metaxas 1996] Dimitris Metaxas. Physics-based deformable models: Applications to computer vision, graphics and medical imaging". Kluwer Academic. 1996.

[Baraf 1991] D. Baraff. Coping with friction for non-penetrating rigid body simulation. Computer Graphics 25(4): 31-40, 1991

[Greenspan 1973] Greenspan, D. Discrete Models. Reading in Applied Mathematics. Addison-Wesley, 1973

[Greenspan 1997] Greenspan, D. Particle Modeling. Birkhauser Ed., 1997.

[Cadoz 89] Cadoz C., Luciani A., Florens JL. (1989). Responsive input devices and sound synthesis by simulation of instrumental mechanisms: the CORDIS system. Computer Music Journal, 8, N°3, pp. 60-73.

[Luciani 1991] Luciani A., Jimenez S., Florens J.L., Cadoz C.& Raoult O., "Computational physics : a modeler simulator for animated physical objects", Proceedings of the European Computer Graphics Conference and Exhibition. Vienna, Austria, Septembre 91, Editeur Elsevier

[Petitot 1994] Jean Petitot. La sémiophysique: de la physique: de la physique qualitatitive aux sciences cognitives. Passion des Formes, à René Thom (M. Porte éd.), E.N.S. Editions Fontenay-Saint Cloud, 1994, 499-545.

[Thom 1988] René Thom. Esquisses d'une sémiophysique. Interéditions 1988.

[Petitot 1989] Jean Petitot. "Forme", Encyclopedia Universalis, XI, 712-728, Paris. 1989.

[Smith 1993] Smith B. "The structure of the Common-sense World". Gestalt Theory. Its Origins, Foundations and Influence. A. Pagnini and S. Poggi Eds. Florence. Olschky.

[Hayes 1985] Hayes P. "The Second Naïve Physics Manifesto". Formal Theories of the Common-sense World. J.R. Hobbs and R.C. Moore eds. 1-36. Norwood, Ablex.

[Nouiri 1994] NOUIRI (J) , CADOZ (C), Luciani A., "The physical modelling of complex physical structures. The mechanical clockwork". - 5th. Eurographics Workshop on Animation and Simulation. Ed. Gérard Hégron and Olov Fahlander. SINTEF, Oslo, Norway Sept 17-18 1994

[Chanclou 1995] Chanclou B., Luciani A. - «Physical models and dynamic simulation of planetary motor vehicles with a great number of degrees of freedom»- Proc of IAS 4 Conf. - IOS Press - 1995 - pp 465-472

[Chanclou 1996] Chanclou B., Luciani A., HABIBI(A), "Physical models of loose soils marked by a moving object" - Proc. of Computer Animation 96 - IEEE computer Soc Press - 1996 - pp36-46

[Jimenez 1993] Jimenez S., Luciani A., "Animation of Interacting Objects with Collisions and Prolonged Contacts", Proceedings of the IFIP WG 5.10 Working Conference. Tokyo April 1993, in Modeling in Computer Graphics - B. Falcidieno & T.L. Kunii Ed., Springer Verlag Pub. – 1993

[Luciani 2000] Luciani A., "From granular avalanches to fluid turbulences through oozing pastes : a mesoscopic physically-based particle model. Proceedings of Graphicon Conference. Moscow. Sept. 2000.

[Luciani 1995b] Luciani A., Habibi A., Vapillon A., Duroc Y.- «A Physical Model of Turbulent Fluids", 6th Eurographics Workshop on Animation and Simulation- Maastricht 1995 - Springer Verlag Ed. "Computer Science Series - pp16-29

[Luciani 1995a] Luciani A., Habibi A., Manzotti E. - "A Multi-scale Physical Models of Granular Materials", Proc. of Graphics Interface '95, 16-19 May 1995, Quebec City, Canada - pp136-146

[Luciani & al., 1991] Luciani A., Jimenez S., Florens J.L., Cadoz C.& Raoult O., "Computational physics: a modeler simulator for animated physical objects", Proceedings of the European Computer Graphics Conference and Exhibition. Vienna, Austria, Septembre 91, Elsevier.

[Habibi 2002] Habibi A., Luciani A.. "Dynamic particle coating. Transactions on visualization and computer graphics". Vol. 8. pp. 383-394. 2002/10-12

[Cadoz et al. 1996] Cadoz C., Luciani A., Florens J.L., "Esquisses". Musical and visual artwork. Création mondiale IJCAI 1996.

[Luciani 2000b] Luciani A., Mémoires Vives. Création mondiale RICA 2000. Rencontres Internationales Informatique et Création Artistique. Grenoble 2000.

[Vaucanson] Jacques de Vaucanson (Grenoble 1709, Paris 1782) http://fr.wikipedia.org/

[Niepce] Nicephore Niepce (1765, 1833). http://www.niepce.com/

8. Acknowledgements

The research has been supported by the French Ministry of Culture, the Institut National Polytechnique of Grenoble (France), and the European FP6 Network of Excellence "Enactive Interfaces" IST 2002 – 000 2114.